Fundamental Challenges for Lithographic Roadmap

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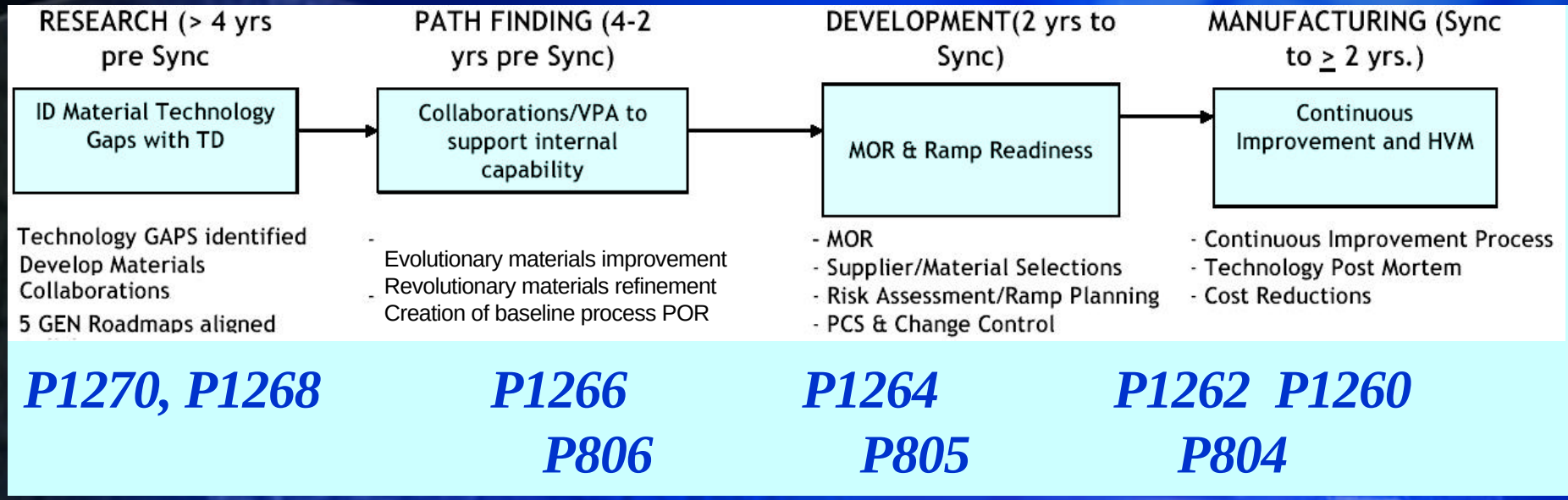
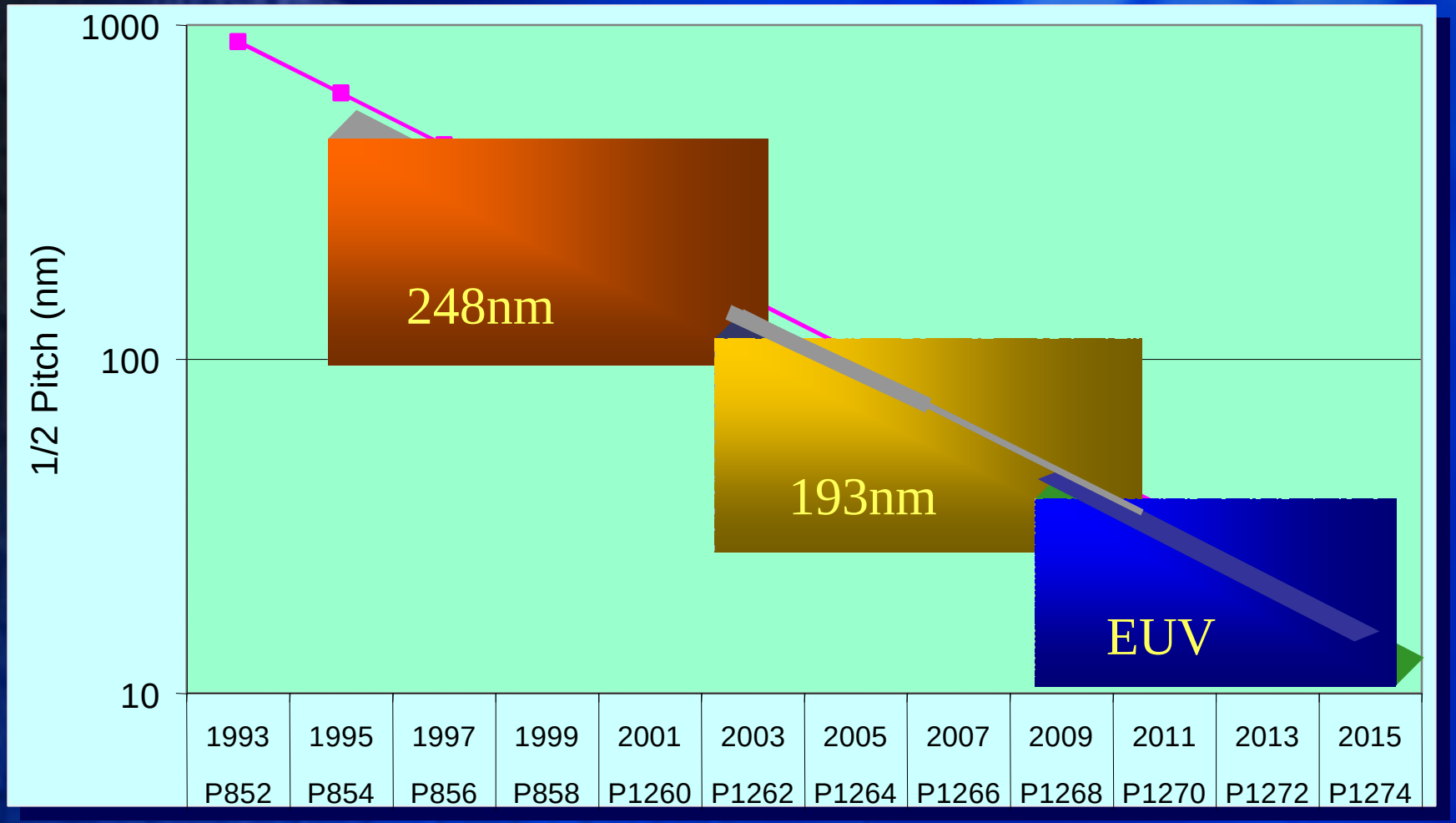
Technology Life Cycle



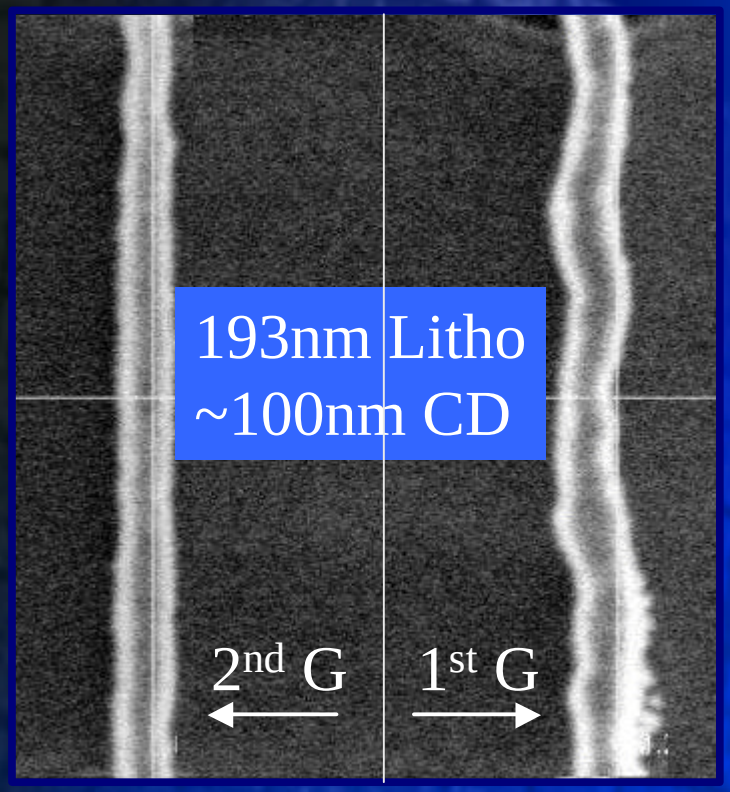
- Early work focuses on fundamental issues
  - Universities, consortia, suppliers
  - Material classes, lithographic approaches screened
- Risk reduced for leading approaches
  - Raws & finished materials performance optimization
  - Understand interactions, repeatability; characterization
- PCS of baseline materials in process → HVM
  - Copy Exactly!, change control, capable metrology

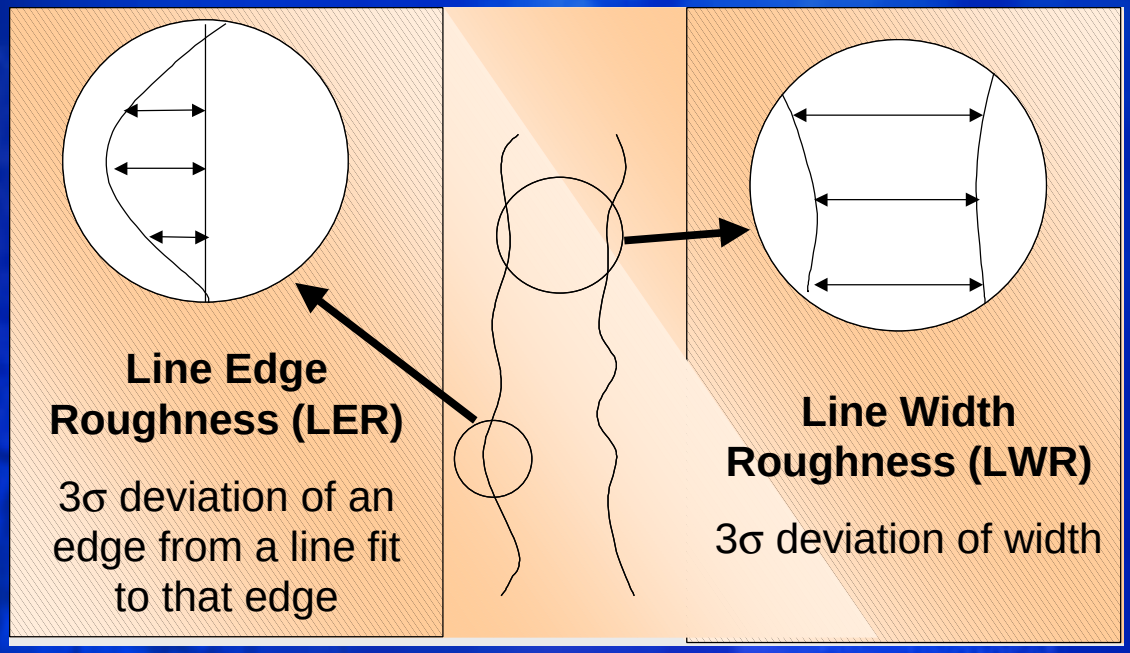
Intel Lithography Roadmap



- 193nm lithography ramping & planned through 45nm node
- EUV planned for 32nm node (~50nm ½ pitch) and beyond

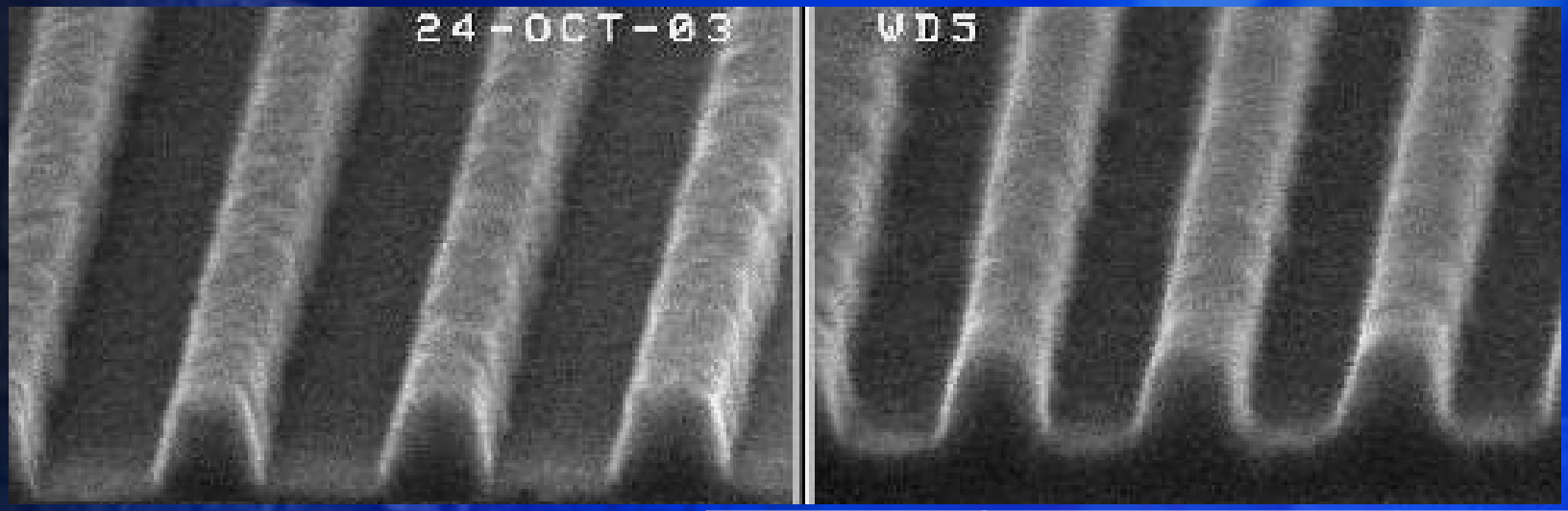
Line Width Roughness

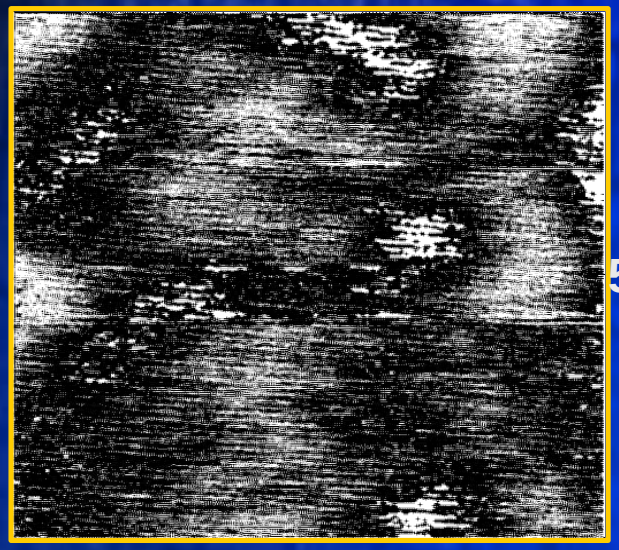




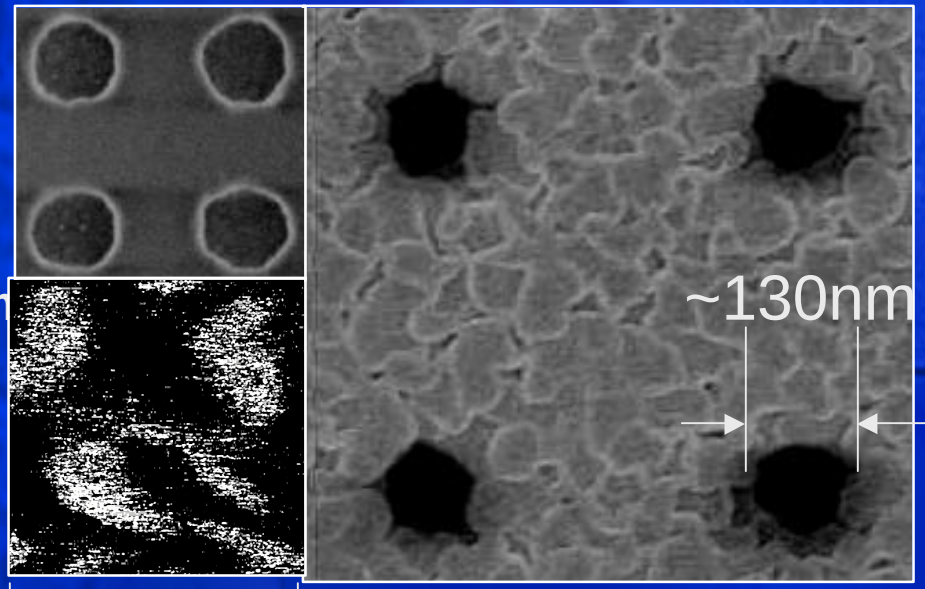
- LWR: variation in cd impacts Ioff, Idsat
- Origins: PSF, material,etch

Roughness



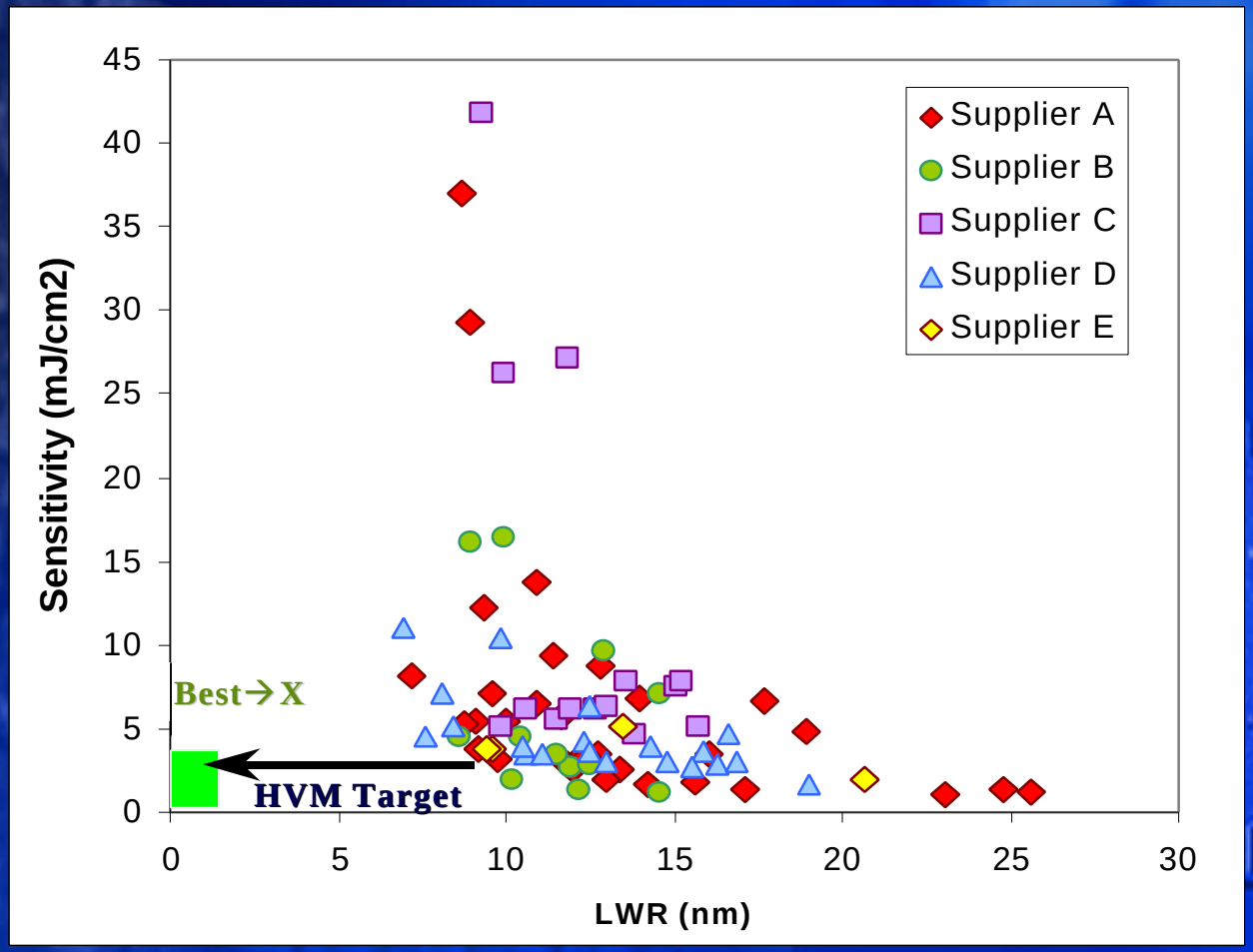


50nm



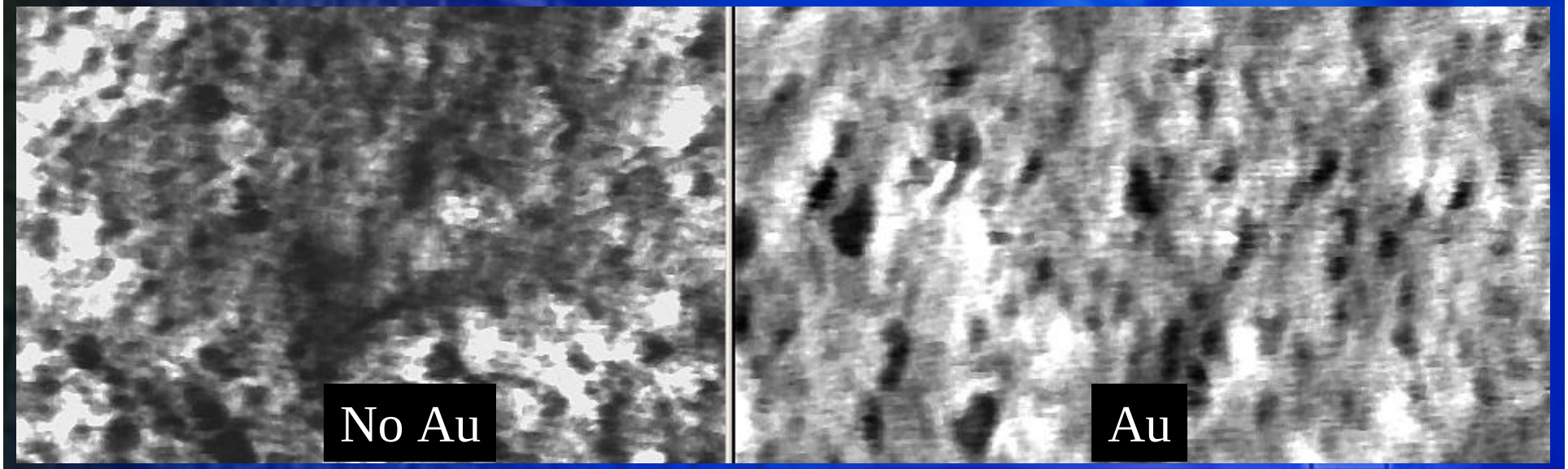
50nm

Speed Vs. Roughness



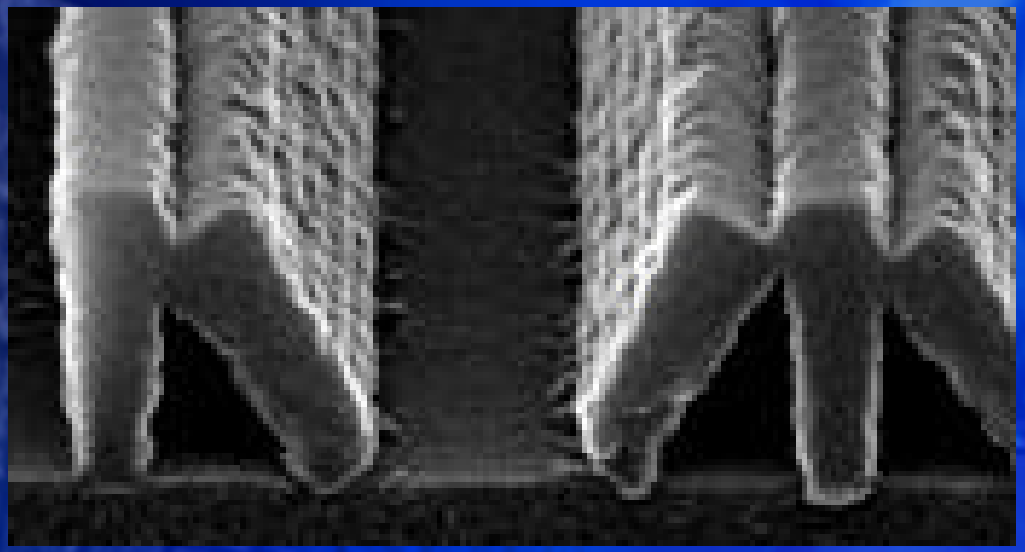
- Material improvements ***key*** to reach targets
  - 193nm <2nm (45nm node)
  - EUV <1.5nm required (32nm node), 2mj/cm^2

Roughness



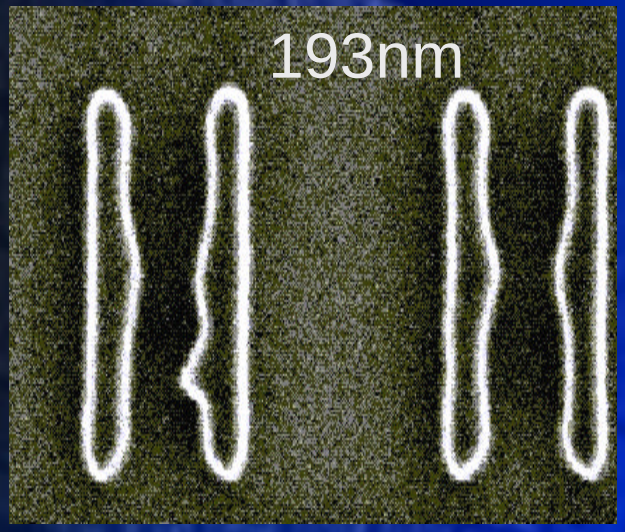
- Tapping mode AFM of resist surface
- Gold Coating highlights larger topology
- Finer structure and texture obscured
- At high resolution, complex structures revealed

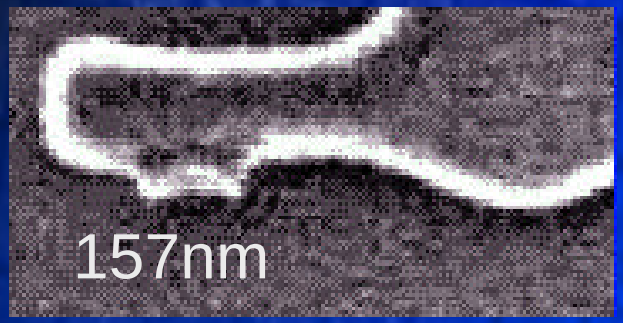
Collapse

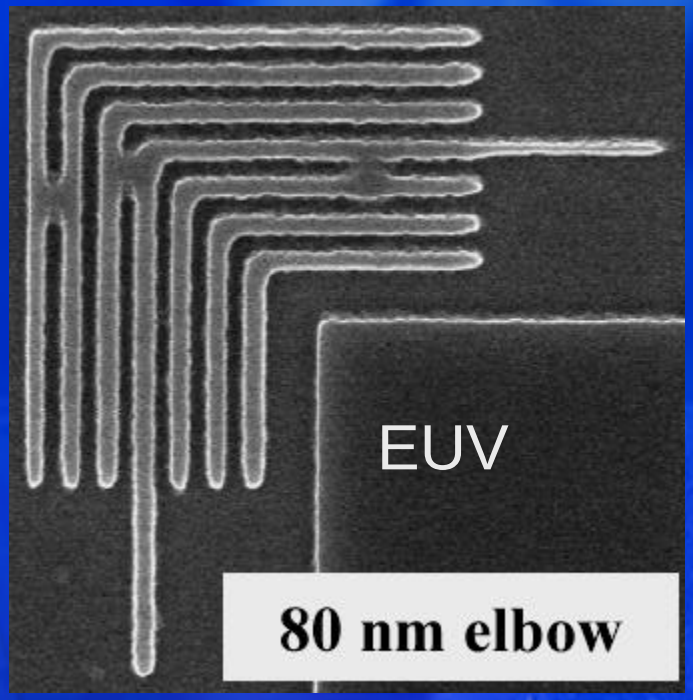


- Dense line/space patterns tend to collapse at small CDs
- Critical Aspect Ratio for Collapse > 3 & undercut worsen
- Substrate-resist compatibility key
- Concerns raised for sub-50nm CD density variation

Defectivity

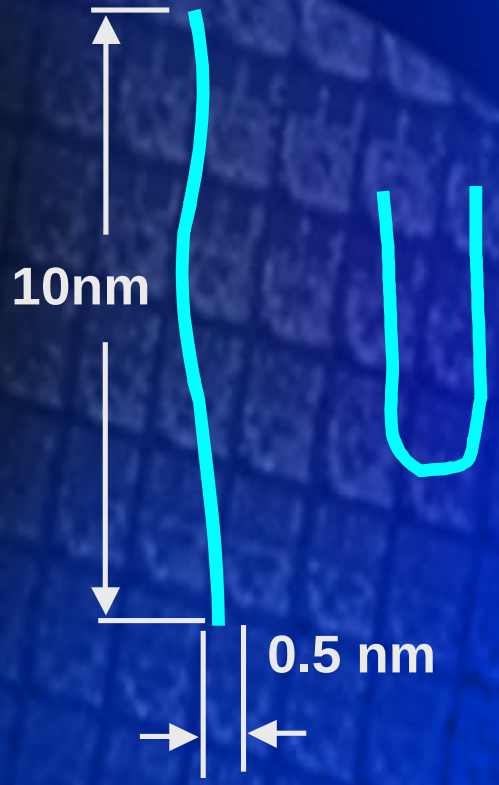


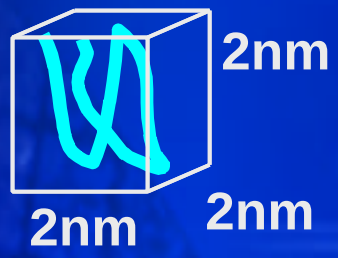


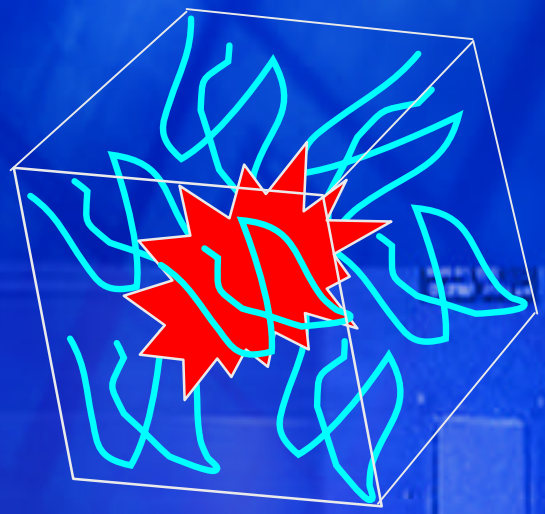


- Defects size shrinking with CD
- Challenging metrology- size, frequency, pattern
- Non-uniform dissolution of material
- Early engagement for materials improvement

Materials Design Consideration



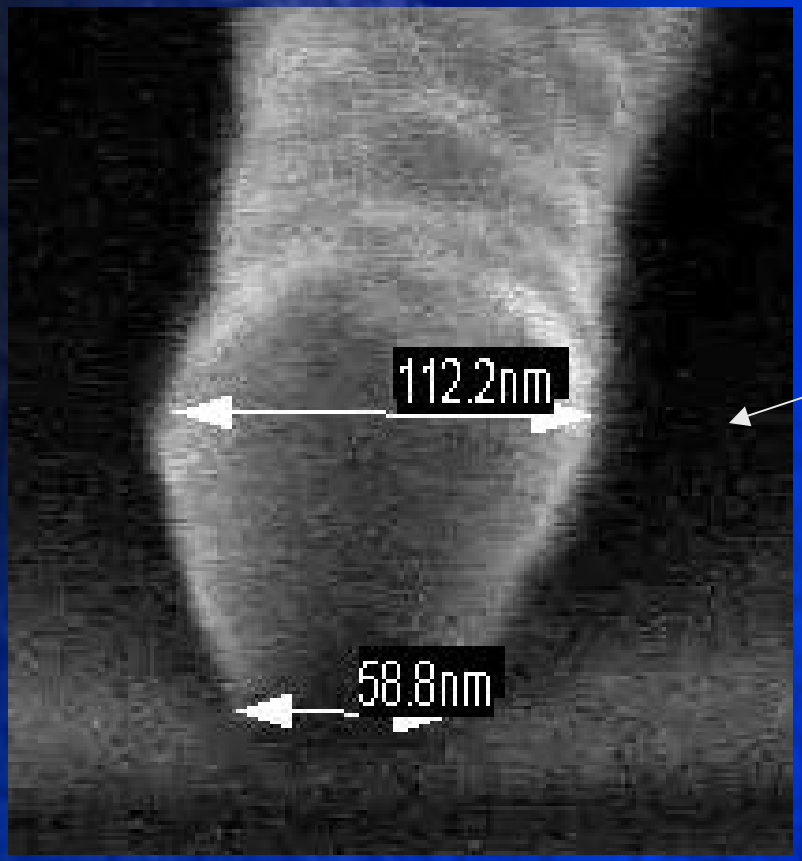


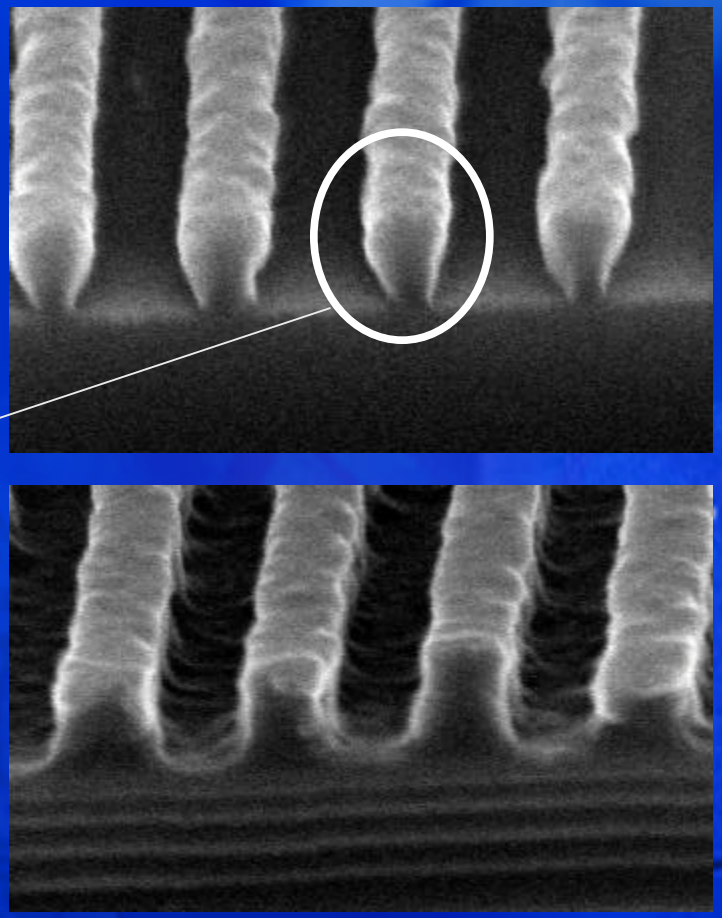


Photoresist “unit cell”

- Polymer has discrete volume
- PAG addresses volume over catalytic cycle
- Sum of addressed polymers in cycle are a limit
- Small regular pixels uniformly distributed is trend

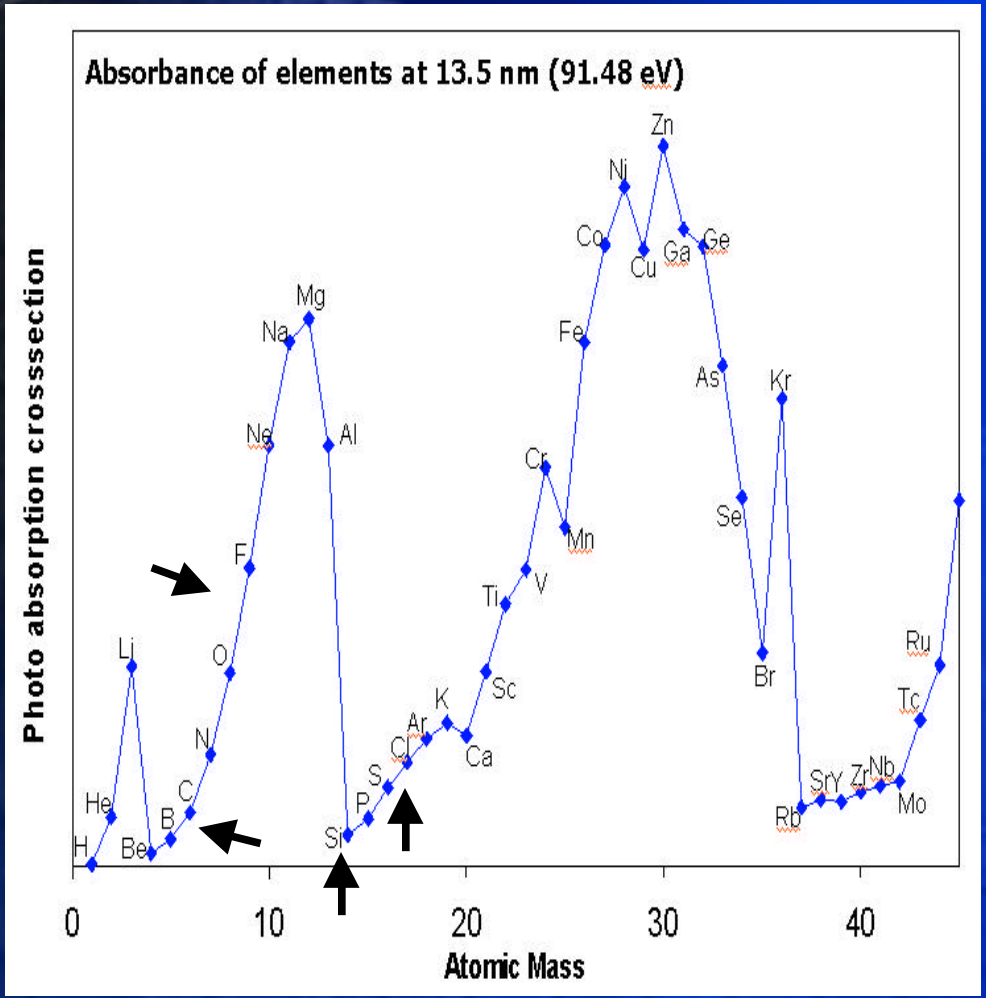
EUV Transparency

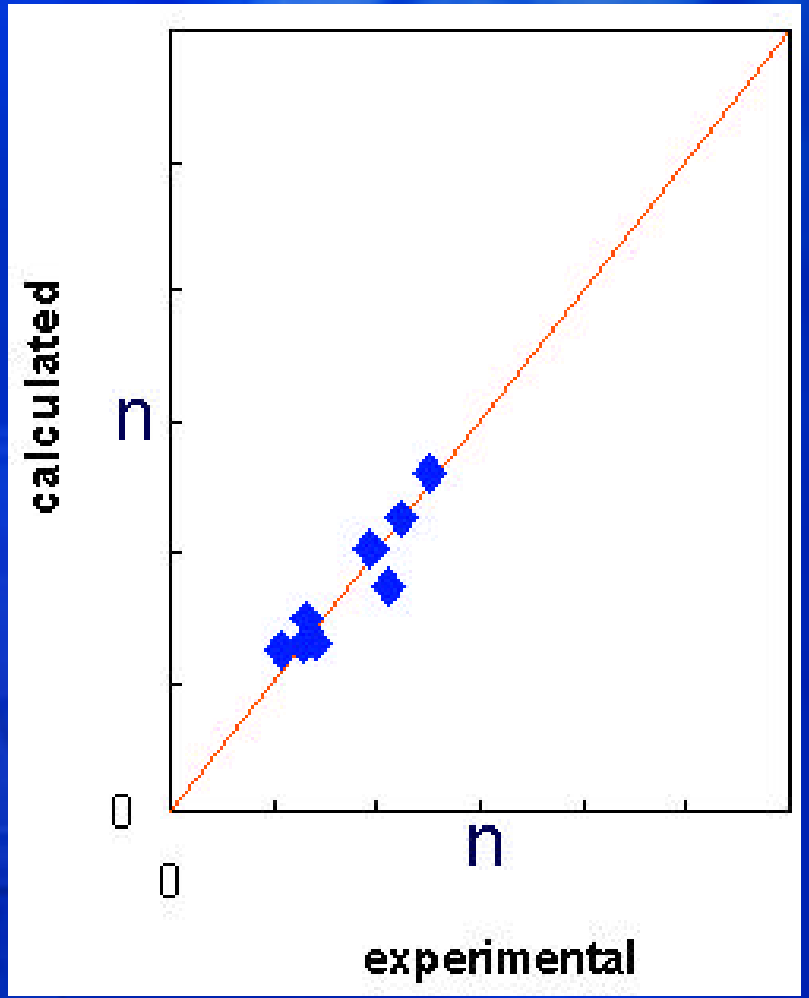




- A < 2.5 to reach 88° side wall; higher A results in…
- Negative tone systems re-entrant: signal loss, collapse
- Positive tone systems suffer ragged footing

EUV Transparency





- F, O common in 248 and 193nm, high for EUV
- B < Si < C ~ P < S < Cl << O << F

Conclusions

- To meet the Intel Roadmap…
- 193nm extension to 45nm Node will face:
  - Substantially tighter roughness requirements
  - Continued reduction in defectivity
- EUV application to the 32nm Node will face:
  - Even tighter roughness requirements, coupled with fast photospeed
  - Transparency improvement
  - Continued reduction in defectivity
- New materials may be key:
  - Polymer composition, structure, control
  - Small molecule distribution control
  - Interfacial energy and structure

Thanks to…

- Intel team: Dr. Heidi Cao, Dr. Manish Chandhok, Dr. Rex Frost, Dr. Steve Jaloviar, Dr. Steve Putna, Dr. Jeanette Roberts, Dr. Adam Schafer, Dr. Wang Yueh
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- Suppliers who fuel the factories!